IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Vol. 8, Issue 12, December 2019

Intriguing Aspects of New Scientific Mind Model as EEG Data Based Algorithm

Dean M. Aslam

BioMEMS and Mind Lab, Electrical and Computer Engineering, Michigan State University, East Lansing, MI 48824

Abstract: Although (a) humans have been dealing with 'what we call mind today' for millions of years and (b) the first use of *mind* became obvious by works of Socrates (470 – 399 BC), a universal scientific definition/model of mind, that scientifically links mind to different parts in Central and Enteric Nervous Systems (CNS and ENS), has not been developed. In this paper, providing a scientific definition/model for the first time of mind and generation/emission of brainwaves, intriguing applications of scientific model of mind, as EEG-data-Based Algorithm across MGBA, are suggested for the first time.

Keywords: Electroencephalogram (EEG), MGBA, CNS, ENS

I. INTRODUCTION

As early humans, for millions of years (Fig. 1), felt their own or others' heartbeat, they considered heartbeat as center of emotions and intelligence. The ancient Egyptians and other traditions (Fig. 1) considered this view as the 'mainstream science' until the discovery of Electroencephalogram (EEG) in 1924 (published in 1929) by Hans Berger [1] who measured alpha wave (8 – 12 Hz). Who controls brain's frontal lobe (logic) and Amygdala (emotions), and their communication with other parts of the brain? When we perceive data through sound, sight, smell, touch and taste, who decides how to react? Can two brains communicate with each other without these senses? Who is the decision maker; mind or brain or childhood memories known as Amygdala Scripts (AS)? As the brain's goal is survival, what is mind's role and how does it interact with brain? What is role of consciousness? If a human decides to jump off a cliff, who is the decision maker and who can interfere? Who controls huge amount of bidirectional data flow along Microbiome-Gut-Brain-Axis (MGBA)? Do EEG signals flow along MGBA? What is the scientific mechanism for generation of brainwaves (EEG signals)? Is a dog not under stress smarter than a human under extreme stress? Currently, there are no scientific answers to most of these questions.
The scientific models suggested in this paper seek answers to most of above questions by proposing that mind, as an algorithm definable and computable by EEG brainwave data generated in MGBA, is the decision maker and leader of everything and anything the living humans and non-humans do and feel [2]. The paper also suggests a scientific model for generation and emission of electromagnetic waves in the frequency range of 0.05 – 500 Hz along MGBA.

II. MODEL OF MIND

The ancient (a) Egyptians considered heart as the center of intelligence rather than brain [3][4] and (b) Chinese culture used the term xin (heart) which has broader meanings including heart, mind, feeling, intention, wisdom, soul, etc. [5]. Aristotle also considered heart as center of intelligence [6]. With number of neurons in Prefrontal Cortex (PFC) and cerebellum defining intelligence, the heart with its 40,000 neurons has no high level intelligence. The role of brain was not recognized until approximately 510 – 440 BC by Alcmaeon [7][8] (Fig. 1).

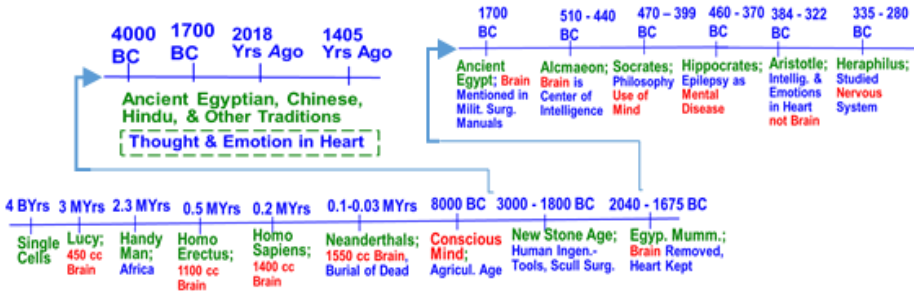

Fig. 1 Early history of heart, brain and mind.

IJARCCE
ISSN (Online) 2278-1021
ISSN (Print) 2319-5940
International Journal of Advanced Research in Computer and Communication Engineering
Vol. 8, Issue 12, December 2019

Although humans have been dealing with 'what we call mind today' for millions of years in the form of behaviors of both animals [9] and humans, a universal scientific definition/model of mind, that scientifically links mind to different parts in MGBA, has not been developed. Different models and views about animal mind [10] [11] and (b) human brain-heart-body [12] exist but not all are supported by mainstream science. According to a psychological model of mind [13], "sensations from the world, sensations from the body, and prior experience form three of the fundamental aspects of all mental life". This model does not quantify 'mental life' or mind. These three fundamental aspects are quantifiable by Electroencephalography (EEG) and the EEG data can help develop an algorithm as explained below. Non-scientific models of consciousness exist [8] but how can scientific mind model help develop a scientific model of consciousness? Are mind and consciousness same? If so, do they extend across MGBA?

The existance of ***mind and consciousness*** are due to neuron firing in MGBA generating electromagnetic waves or brainwaves. The reported brainwave frequencies, measured by Electroencephalograph (EEG), are in the frequency range of 0.05 – 500 Hz measured along MGBA [14][15]. Scientific model of attention level of mind developed [16] using alpha and beta wave EEG data is used in mind-controlled robot [17] and games [18]. **Consciousness**, if considered state of mind, is also an **EEG-data-based algorithm**. The neuron firing in MGBA is also applicable to develop algorithms for factors mentioned in Fig. 2 that also shows parts of brain involved for development of algorithms for such factors. For example, empathy algorithm, involving insula and PFJ [19][20], should be possible using EEG data from PFJ and insula.
The scientific model of mind's attention level developed [16] using alpha and beta wave EEG data is not very accurate and cannot be applied to factors mentioned in Fig. 2. Here is a procedure for accurate algorithm development using EEG data from particular brain parts:

a) Identify the EEG data from particular brain parts using simultaneous EEG and functional Magnetic Resonance Imaging (fMRI) experiments [21][22][23].
b) Identify sections of data responsible for a particular algorithm (any of the factors mentioned in Fig. 2).
c) Develop algorithm by finding FFT (Fast Fourier Transform) of relevant EEG data.
d) Test these algorithms under different conditions.

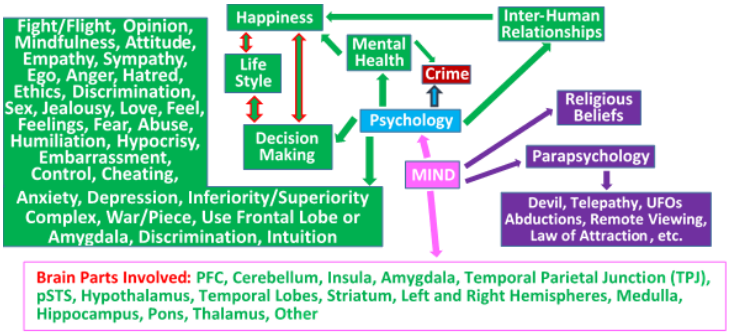

Fig. 2 Suggested mind model dependent on interrelated factors.

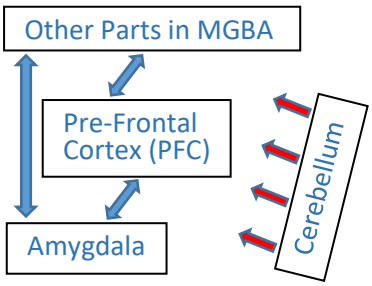

Fig. 3 A comprehensive scientific mind/consciousness model.

Fig. 3 shows a model for algorithms involving PFC, Amygdala and Cerebellum. While the use of PFC (logic) and Amygdala (emotions) will play an important role in developing the mind algorithms for most of the factors mentioned in Fig. 2, why is cerebellum involved in the mind model? Of the 86 billion neurons in brain [24], 99% are in cerebral and cerebellar cortexes [25]. Due to exponential growth of knowledge about cerebellum in the last three decades, including its role in emotional

IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Vol. 8, Issue 12, December 2019

processing [26], any model of mind must include the new roles of cerebellum. In addition to its motor role, according to clinical, experimental, neuroimaging and neurophysiological investigations research, the cerebellum is involved in cognitive, affective, social, and emotional processing [26] because cerebellum acts as the computational unit of the brain. The mind, modeled as algorithm computable by EEG brainwave data, is the decision maker and leader of everything and anything the living humans and non-humans do and feel.

Role of e^x in FFT Algorithm: What is the role of natural exponential function (e^x) in FFT algorithm? The constant e, discovered in 1683 by Jacob Bernoulli [27] while studying compound interest as defined by eq. (1), has multidisciplinary applications today:

$e = \lim_{n\to\infty} \left(1 + \frac{1}{n}\right)^n$, **e = 2.71828** when ***n is very large*** approaching infinity (1)

This paper introduces an unusual definition of e^x: The mathematical modelling of a physical quantity, ***depending on a very large number of particles or processes n***, is only possible by e^x and not by 2^x or 3^x. Here are some examples; (a) growth of a tumor [28], (b) diffusion current across a p-n junction [29], (c) drug half-life in the body [30], (d) increase of human height, (e) growth of a rock, and (f) radioactive decay [31].

III. MODEL OF BRAINWAVE GENERATION AND EMISSION

Studies have tried to explain (a) brainwave generation in the cortex [32], (b) theories of consciousness [33], (c) integrated consciousness [34], (d) travelling waves [35], and (e) methodology for mapping networks of structural connectivity in the brain [36]. Recent studies have measured the brainwaves originating from the limbic system [21][22][23] showing that brainwaves are generated in other parts of the brain, perhaps also along the Microbiome-Gut-Brain-Axis (MGBA), and not just in the cortex. However, these studies are unable to explain (a) the wavelength and frequency ranges of the emitted and measured brainwaves, (b) how brainwaves with a wavelength range of 1 billion - 50 million meters are possible. Currently, there is no universal scientific model of brainwave emission across MGBA. As the proposed mind model extends EEG signals across MGBA, how to explain brainwave emission across MGBA? For example, how are 0.03 Hz (10^{10} meters) brainwaves generated and emitted? For the ***first time***, this paper attempts to explain generation of brainwaves using the ***dipole antenna model*** of electromagnetic waves [37].

There are approximately 860 trillion neuron connections [38] among the 86 billion neurons in the brain [39]. Such connection paths of neural current flow (in series and parallel), caused by action potentials, can act as an antenna emitting electromagnetic waves. Thus, the currents through neural paths of axons, insulated by myelin sheath, can form very long paths (antennas) emitting electromagnetic waves. According to the model of brainwaves suggested in this paper, brainwaves result whenever a large number of neurons are firing along the neural paths of axons. With axon ion densities of approximately 10^{15} cm^{-3}, action potential generation time of approximately 10^{-3} s (dendrite changes the axon potential from 0 to approx. 70 mV in a single neuron firing) and ionic currents of approximately 10^{-7} A [40], this paper suggests to use the dipole antenna model to explain the emitted frequencies and wavelengths of brainwaves. The axon length is in the range of 1 – 1000 mm with myelin insulation (Fig. 4) and a synapse gap of 20-40 nm. The electromagnetic waves of 3 and 0.03 Hz have wavelengths of 10^8 and 10^{10} m, respectively. Huge neural connection paths are possible due to very small synapse gap allowing neural currents to flow across multiple neurons making this path a very long antenna (Fig. 4) radiating e.m. waves (brainwaves).

A wavelength of 10^{10} m (0.03 Hz) will require a dipole antenna length of $5x10^9$ m. Other studies have suggested (a) average short- and long-range connection lengths of 8.4 x 10^8 m [35][36], and (b) distributed and integrating network connections [41]. The delta waves (0.3 – 3 Hz) will require a neural connection length range of 5 – 50 $x10^7$ m causing neuron firing in most of the brain parts.

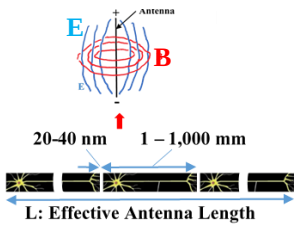

Fig. 4 Antenna length L; E and B fields.

IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Vol. 8, Issue 12, December 2019

That makes sense as the brain repairs itself during deep sleep dominated by delta waves [42]. However, realizing that of the 86 billion neurons in brain [43] 99% are in cerebral and cerebellar cortexes [44], these two cortexes may have enough connections to produce antenna lengths needed for delta waves. With expression of some doubts about the accuracy of predicted neural paths [35] and for the existence of ultrashort frequencies (< 0.05 Hz), we need other ideas for appropriate neural paths to use the antenna model. While the delta waves dominate in deep sleep, they are always emitted even if we are awake. This may be due to the fact that 99% of the total neural connections, coming from cerebral and cerebellar cortexes [44], are active in many of brain factors mentioned in Fig. 2.

IV. INTRIGUING APPLICATIONS OF MIND MODEL

For a reliable scientific model of mind EEG data generation between PFC, Amygdala and Cerebellum (Fig. 3) is crucial. Some intriguing applications of scientific models of mind, as EEG-data-based algorithm across MGBA, are suggested for the first time:

1. Ants Colony and Human Brain Run Without a Physical Leader:

Interestingly, an ants colony [45][46] and human MGBA [39] have two things in common; (a) the goal, assisted by multiple parts, is survival and (b) multiple parts are organized without a 'physical entity' as a leader. Ants' antennas, coated with cuticular hydrocarbons (CH) specific to their colony [47], use CH for communication with intra colony ants. According to model suggested by this paper the 250,000 neurons in ant brain detect CH and a large number of ants in a colony generate data leading to an ***algorithm that is leader*** of the colony. The data gathered by external CH sensors on ant's antennas can lead to a similar algorithm.

In contrast, the EEG data generated in human MGBA leads to an algorithm that is the leader in the human brain. This leader is the mind. Different mind factors mentioned in Fig. 2 are explainable by mind algorithms based on EEG data generated by relevant brain parts.

2. Can a Dog be More Intelligent Than a Human?

As the PFC of a human under extreme stresss may have less functional neurons (partial or total PFC shutdown) available [48] [49] than PFC of a dog not under stress, the mind of human under stress has less intelligence than that of a dog. A similar situation may occur if a human uses emotional part of the mind (Amygdala). The decisions made by a human under extreme stress will be very dangerous, especially if the person holds a public office.

3. Does mind Control Emotions and Logic?

Emotions and logic, affected by neuron firing in PFC, Amygdala and Cerebellum, relate to (a) childhood memories (Amygdala Scripts) and experiences, and (b) brought-up and education. Logical thinking relates to neuron firing mainly in PFC, other cortical parts and cerebellum. Human emotional and logical thinking depend on bidirectional communication of cerebral neurons with other parts of the brain and gut, in particular Amygdala and Cerebellum. Amygdala, with its 12-13 Million neurons [50], controls emotions by using permanent memory in Hippocampus. Thus, whether mind of a person behaves logically depends upon number of functional PFC neurons or level of stress.

4. Personality Algorithms

The fundamental personality dependent data, generated by the limbic system in general and Amygdala in particular, affects all mind algorithms. Thus, the data from Amygdala [51] [52], PFC and Cerebellum plays a fundamental role in defining the personality algorithm, differentiating one human from another. According to the mind model presented in this paper, the personality algorithm is the leader (decision maker) of all the parts in the Microbiome-Gut-Brain-Axis.

5. Can Mind Model Help Narcissist Personalities?

What is Narcissistic Personality Disorder (NPD) [53][54]? The mind of narcissists (a) feels inferior (b) is arrogant, disparaging and self-absorbed and (c) lacks empathy or empathy hindered by extreme stress. Narcissists found in general public including pastors [55] and other religious leaders, pose a danger. Stress induced changes in right insular regions may affect NPD [56] because this reduces the EEG data required for a normal mind function. The reason for this stress is traceable to narcissist's Amygdala Scripts (AS) [51]. Since mind can help reduce stress by exercise and discovering narcissist's AS, one interesting way is to build and use Narcissism controlled robot (will be opposite of Empathy controlled robot) by EEG data from TPJ and Insula regions leading a ***narcissist algorithm***.

IJARCCE
ISSN (Online) 2278-1021
ISSN (Print) 2319-5940
International Journal of Advanced Research in Computer and Communication Engineering
Vol. 8, Issue 12, December 2019

6. Can Mind Affect Neurogenesis?

Interestingly, the only area of the brain where neurogenesis (ability to divide to make new cells) continues throughout life is the hippocampus, an area essential to memory encoding and storage. Neurogenesis increases by learning, exercise [57] [58] and sex but decreases with stress, sleep deprivation and aging. Does mind affect aging? It does through controlling stress [59]. The slowdown of biological aging by slowing shortening of DNA telomere through diet, exercise and good sleep is possible [60]. The mind controls diet, exercise and good sleep. Amygdala Scripts [51] [52][61], permanently stored in hippocampus, affect mind and personality. AS can affect neurogenesis through stress. There is some evidence that neurogenesis can also take place in midbrain and striatum [62] areas. Decision making is affected by Amygdala [63][64][65]. Thus, according to the mind model of this paper, for an accurate algorithm, one has to combine the Amygdala, PFC and ENS data resulting in Personality Algorithm. The role of Microbiome, communicating with amygdala [61], is very important for development of personality algorithms and neurogenesis.

7. Can Human Mind Detect Social Interactions Leading To 'Human Interaction' Algorithms?

What parts of brain are involved in social interactions? Are mind algorithms for social interactions, empathy and other aspects of human behavior possible? The parts of the brain, related to personality, are also very important for the scientific model of mind including *insula, Temporal-Parietal Junction (TPJ) and the right side of the posterior Superior Temporal Sulcus (pSTS)*. Mental state has been studied [66] by showing videos of positive or negative interaction between two people; the pSTS as well as neighboring TPJ are involved [66]. TPJ also helps interpret the behavior of other people based on an understanding of their minds [67] according to theory of mind representing another person's mental states.

Insula [68], a socio-emotional region in the anterior-ventral insula, leads to empathy (ability to perceive, understand and experience others' feelings), social cognition, subjective feeling and social interaction. As shown in Fig. 3, such a mind model becomes very complex because portion of brainwaves coming from one or more of these parts (Fig. 3) will be needed for developing algorithms for the personality related factors in Fig. 2. Again, it is very important to find the brainwaves originating from these parts using the fMRI and EEG experiments at the same time. The model presented in Fig. 3 is complex and requires a multidisciplinary and transdisciplinary approach to get the data needed.

8. Leader of Brain in Sleep?

How does brain repair itself during deep sleep? Who is the leader during the repair process? Based on scientific model of this paper, mind is the leader of brain in sleep and awake states. The brain repairs itself in deep sleep [69] using delta waves. The stronger (>150 µV) delta waves [70][71] in sleep, observed for sleepwalkers, are associated with the higher homeostatic pressure present early during the sleep period. The fact that relatively high delta wave signal is present for repairing the brain indicates delta waves generated in the brain during deep sleep affect some or all parts of the brain. Are the brainwaves, especially with ultrashort frequencies, measureable in ENS (connected to CNS through Vagus nerve)? Can brainwaves travel outside the brain? Can low-impedance sensor materials, such as 2D graphene EEG sensors [72], detect brainwaves at a distance from the brain? Graphene EEG sensors may detect very weak EEG signals (pV) not requiring skin contact. Can brain waves from one brain enter another brain and affect the other brain? Currently there is no scientific answer for most of these questions.

We know that transcranial stimulation enters the brain and affects parts of the brain because typical stimulation currents are 1 mA. Transcranial direct current stimulation (tDCS) alters spontaneous cortical activity, while transcranial alternating current stimulation (tACS) and transcranial random-noise stimulation (tRNS) are presumed to induce or interfere with oscillations of cortical networks [73][74].

9. Does a Patient Know More About State of Patient Than a Medical Doctor?

Who has the most knowledge about patient's actual condition; mind of a doctor or mind of a patient? Obviously, doctor is a medical professional and typical patient is not. This paper argues that patient's mind knows far more his/her condition than a doctor does. When a doctor gets the results of various tests/procedures doctor explains the results to the patient making patient's mind knowledgeable. Then patient's mind constantly receives information, from his brain and body, that Dr. has no access to. According to a psychological model of mind [13], "sensations from the world, sensations from the body, and prior experience form three of the fundamental aspects of all mental life". Patient's mind as an algorithm has access to much more data than doctor's mind. Unless telepathy becomes a reality, the patient's mind knows about patients' condition more than a doctor. Now, as mind is leader and decision maker, the patient's mind with doctor's help can improve the quality of life and longevity. The people living in blue zones, with no doctor available, use their mind for healthcare [75] to live 100 years or more.

10. Does Charity Curb Creativity and Fairness Encouraging Corruption?

Individuals and nations relying on charities may disappear due to lack of survival skills and creativity. Someone, getting charity without any effort, becomes less creative. People allowed to question anything and everything when they are growing up, become very creative. One example is Finland where children can question anything and everything. In today's world religious people are far less creative because they are not allowed to question everything when growing up. Unfortunately, followers of all Prophets are not creative although their Prophets were extremely creative. Today Finnish are most creative [76] because their children question everything and anything and are not supported by charity.

V. CONCLUSIONS

This paper, for the first time, presents a universal scientific definition/model of mind linking scientifically to different parts in central and enteric nervous systems (CNS and ENS). In particular, intriguing applications of scientific model of mind, as EEG-data-based algorithm across MGBA, are suggested for the first time.

REFERENCES

[1]. H. Berger, "Über das Elektrenkephalogramm des Menschen", Archive für Psychiatre und Nervenkrankheiten, 87, 527-570, 1929; "About EEG of a human", Archives for Psychiatric and Nerve Diseases, 87, 527-570, 1929.
[2]. D.M. Aslam, "Mind as EEG Data Based Algorithm is Decision Maker not Brain", eLetter Science, 2019; https://science.sciencemag.org/content/313/5787/684/tab-e-letters
[3]. M. A. Loukas, P. Youssef, J. Gielecki, J. Walocha, K. Natsis, and R. S. Tubbs, "History of Cardiac Anatomy: A Comprehensive Review from the Egyptians to Today", Clinical Anatomy 29:270–284 (2016).
[4]. M. LOUKAS, M. HANNA, N. ALSAIEGH, M. O. M. SHOJA, and R. S. TUBBS, "Clinical Anatomy as Practiced by Ancient Egyptians", Clinical Anatomy 24:409–415 (2011).
[5]. J. Li, C. Ericsson and M. Quennerstedt, "The meaning of the Chinese cultural keyword xin", J. Languages and Culture, Vol. 4(5), pp. 75-89, 2013.
[6]. C.G. Gross, "Aristotle on the Brain", The Neuroscientist, vol. 1(4), 1995.
[7]. Alberto Debernardi et al., "Alcmaeon of Croton", Neurosurgery, vol 66 (2), 2010.
[8]. G. G. Celesia, "Alcmaeon of Croton's Observations on Health, Brain, Mind, and Soul", J. History of Neurosciences, 21, 409–426, 2012.
[9]. Birds' intelligence in mate selection; https://www.youtube.com/watch?v=rX40mBb8bkU
[10]. Robert Lurz, Historical reasoning; https://www.iep.utm.edu/ani-mind/
[11]. Lurz, R. (2009). The Philosophy of Animal Minds: New Essays on Animal Thought and Consciousness. Cambridge: Cambridge University Press.
[12]. Rollin McCraty, "Heart–Brain Neurodynamics: The Making of Emotions"; https://www.researchgate.net/profile/Rollin_Mccraty2/publication/275613419_Heart-Brain_Neurodynamics_The_Making_of_Emotion/links/55938d0008ae1e9cb429a7df.pdf
[13]. L. F. Barrett, "The Future of Psychology Connecting Mind to Brain", Perspectives Psychological Science, vol 4, 2009.
[14]. Buzsaki G, Draguhn A., "Neuronal Oscillations in Cortical Networks", Science, 304:1926, 2004; [PubMed: 15218136].
[15]. R. T. Canolty1 et al., "High Gamma Power Is Phase-Locked to Theta Oscillations in Human Neocortex", Science, September 15; 313(5793): 1626–1628. doi:10.1126/science.1128115, 2006.
[16]. Ning-Han Liu, Cheng-Yu Chiang and Hsuan-Chin Chu, "Recognizing the Degree of Human Attention Using EEG Signals from Mobile Sensors" Sensors, 13, 10273-10286, 2013.
[17]. D.M. Aslam, "Mind-controlled LEGO robot Using Fabric-Embedded Microsystems"; www.youtube.com/watch?v=LdSBQy5_yyY&feature=youtu.be
[18]. Gürkök, H. (2012), "Mind the Sheep! User Experience Evaluation & Brain-Computer Interface Games", Enschede: University of Twente. https://doi.org/10.3990/1.9789036533959
[19]. Tania Singer, Hugo D. Critchley and Kerstin Preuschoff, "A common role of insula in feelings, empathy and uncertainty", Trends in Cognitive Sciences, 13 (8), 2009.
[20]. J. Zaki and K. Ochsner "The neuroscience of empathy: progress, pitfalls and promise", Nature Neuroscience, 15 (5), 2012.
[21]. S.D. Jackob N. Keynan, Yehudit Meir-Hasson, Gadi Gilam, Avihay Cohen, Gilan Jackont, Sivan Kinreich, Limor Ikar, Ayelet Or-Borichev, Amit Etkin, Anett Gyurak, Ilana Klovatch, Nathan Intrator, and Talma Hendlernm, "Limbic Activity Modulation Guided by Functional Magnetic Resonance Imaging–Inspired Electroencephalography Improves Implicit Emotion Regulation", Biological Psychiatry, 2016; 80:490–496 www.sobp.org/journal
[22]. M.S. George, "Is Functional Magnetic Resonance Imaging-Inspired Electroencephalogram Feedback the Next New Treatment in Psychiatry?", Biological Psychiatry, 2016; 80:422–423 www.sobp.org/journal
[23]. V. Zotev, R. Phillips, H. Yuan, M. Misaki, J. Bodurka, "Self-regulation of human brain activity using simultaneous real-time fMRI and EEG neurofeedback", NeuroImage, 85, 985–995, 2014.
[24]. C.S. von Bartheld and S. Herculano-Houzel, "The search for true numbers of neurons and glial cells in the human brain: A review of 150 years of cell counting", Comparative Neurology, 524, 3865-3895, 2016.
[25]. S. Herculano-Houzel, "Coordinated scaling of cortical and cerebellar numbers of neurons", Frontiers in Neuroanatomy, 4, 2010.
[26]. M. Adamaszek1, et al., "Consensus Paper: Cerebellum and Emotion", Cerebellum, 16, 552–576, 2017.
[27]. See Jacob Bernoulli; https://en.wikipedia.org/wiki/E_(mathematical_constant)
[28]. J.A. Adam, "A simplified mathematical model of tumor growth", Math. Biosciences, Vol 81, (2), 229-244, 1986.
[29]. P-N junction I-V characteristics; http://web.mit.edu/6.012/www/SP07-L14.pdf
[30]. Drug half-life: https://en.wikipedia.org/wiki/Biological_half-life
[31]. Radioactive decay: https://en.wikipedia.org/wiki/Half-life
[32]. Paul L. Nunez, "The Brain Wave Equation: A Model for the EEG", Mathematical Biosciences 21, 219-291, 1974.

[33]. Dejan Raković, " Hierarchical Neural Networks And Brainwaves: Towards A Theory Of Consciousness", pp. 189-204, Lj. Rakić, G. Kostopoulos, D. Raković, and Dj. Koruga, eds., "Brain & Consciousness", Proc. ECPD Workshop, Belgrade, Yugoslavia, 1997.
[34]. Paul L Nunez and Ramesh Srinivasan, "A theoretical basis for standing and traveling brain waves measured with human EEG with implications for an integrated consciousness", Clin. Neurophysiol., 117(11): 2424–2435, 2006.
[35]. Fr. Kaiser, "Coherent Oscillations in Biological Systems II Limit Cycle Collapse and the Onset of Travelling Waves in Fröhlich's Brain Wave Model", Zeitschrift für Naturforschung A (Journal of Physical Sciences A), vol. 33, Pages 418–431, ISSN (Online) 1865-7109, ISSN (Print) 0932-0784, 1978. DOI: https://doi.org/10.1515/zna-1978-0404.
[36]. Hagmann P, Kurant M, Gigandet X, Thiran P, Wedeen VJ, Meuli R, et al., "Mapping Human Whole-Brain Structural Networks with Diffusion MRI", PLoS ONE, 2(7), e597, 2007; https://doi.org/10.1371/journal.pone.0000597
[37]. D.M. Aslam, "Dipole Antenna Scientific Model of Brainwave Emission Frequencies of 0.05 - 500 Hz", eLetter, Science, 2019; https://science.sciencemag.org/content/313/5793/1626/tab-e-letters
[38]. Synaptic Connections: https://aiimpacts.org/scale-of-the-human-brain/
[39]. B.W. Mel, "In the brain, the model is the goal", Nature Neuroscience 3, 1183 (2000).
[40]. Dejan Raković, " Hierarchical Neural Networks And Brainwaves: Towards A Theory Of Consciousness", pp. 189-204, Lj. Rakić, G. Kostopoulos, D. Raković, and Dj. Koruga, eds., "Brain & Consciousness", Proc. ECPD Workshop, Belgrade, Yugoslavia, 1997.
[41]. Tegan McCaslin, "Transmitting fibers in the brain: Total length and distribution of lengths"; https://aiimpacts.org/transmitting-fibers-in-the-brain-total-length-and-distribution-of-lengths/
[42]. R. Saxe and N. Kanwisher, "People thinking about thinking people: The role of the temporo-parietal junction in 'theory of mind'", Neuro Image, 19 (4), 1835-1842, 2003: https://doi.org/10.1016/S1053-8119(03)00230-1
[43]. M. Dorigo and T. Stützle "Ant Colony Optimization: Overview and Recent Advances", 2019; http://code.ulb.ac.be/dbfiles/DorSta2018MetaHandBook.pdf
[44]. L. Marner, Jens R. Nyengaard ,Y. Tang and B. Pakkenberg, "Marked loss of myelinated nerve fibers in the human brain with age", J. Comparative Neurology, 462 (2), 144-152, 2003; https://doi.org/10.1002/cne.10714.
[45]. M. Dorigo and T. Stützle "Ant Colony Optimization: Overview and Recent Advances", 2019; http://code.ulb.ac.be/dbfiles/DorSta2018MetaHandBook.pdf
[46]. M.J. Green and D.M. Gordon, "Cuticular hydrocarbons inform task decisions", Nature 423, 32 (2003).
[47]. M.J. Greene, D.M. Gordon, "Interaction rate informs harvester ant task decisions", *Behavioral Ecology*, Vol. 18 (2), 451–455, 2007; https://doi.org/10.1093/beheco/arl105
[48]. C. Listona, B. S. McEwen, and B. J. Casey, "Psychosocial stress reversibly disrupts prefrontal processing and attentional control", PNAS, 106 (3), 2009.
[49]. D. Datta and A. F. T. Arnsten, "Loss of Prefrontal Cortical Higher Cognition with Uncontrollable Stress: Molecular Mechanisms, Changes with Age, and Relevance to Treatment", Brain Sci., 9, 113, 2019.
[50]. Thomas A. Avino, Nicole Barger, Martha V. Vargas, Erin L. Carlson, David G. Amaral, Melissa D. Bauman, and Cynthia M. Schumann, "Neuron numbers increase in the human amygdala from birth to adulthood, but not in autism", PNAS, 115 (14), 3710-3715, 2018; https://doi.org/10.1073/pnas.1801912115
[51]. Tim Stokes, "What Freud Did not Know", Rutgers University Press 2010; Amygdala Scripts Definition; http://www.amygdalascripts.com/definition-of-amygdala-scripts/
[52]. Dante Cicchetti, "An Odyssey of Discovery: Lessons Learned through Three Decades of Research on Child Maltreatment", American Psychologist, 59(8), 731-741353, 2004.
[53]. Lars Schulze, Isabel Dziobek, Aline Vater, Hauke R. Heekeren, Malek Bajbouj, Babette Renneberg, Isabella Heuser, Stefan Roepke, "Gray Matter Abnormalities In Patients With Narcissistic Personality Disorder", *J. Psychiatric Research*, 2013; DOI: 10.1016/j.jpsychires.2013.05.017
[54]. Jeffrey Kluger, "The Narcissist Next Door; Understanding the Monster in Your Family, in Your Office, in Your Bed -in Your World"; https://www.cambridge.org/core/services/aop-cambridge-core/content/view/EB78D5E3445EE845F63585083D0976EA/S2056469400003363a.pdf/div-class-title-span-class-italic-the-narcissist-next-door-understanding-the-monster-in-your-family-in-your-office-in-your-bed-in-your-world-span-by-jeffrey-kluger-riverhead-books-2015-16-00-pb-288-pp-isbn-9781594633911-div.pdf
[55]. R Glenn Ball, Darrell Puls, Steven J Sandage, "Let us prey; the plague of narcissist pastors and what we can do about it"; https://www.worldcat.org/title/let-us-prey-the-plague-of-narcissist-pastors-and-what-we-can-do-about-it/oclc/994841373?referer=di&ht=edition
[56]. C.S.Mizen, "Narcissistic disorder and the failure of symbolisation: A Relational Affective Hypothesis", Medical Hypotheses, vol 83, 254-262 (2014); https://doi.org/10.1016/j.mehy.2014.05.012
[57]. H. van Praag, G. Kempermann and F. H. Gagenature, "Running increases cell proliferation and neurogenesis in the adult mouse dentate gyrus", Nature Neuroscience, 2(3), 1999.
[58]. H. van Praag, "Neurogenesis and Exercise: Past and Future Directions", Neuromol Med, 10, 128–140, 2008.
[59]. E. S. Epel, E. H. Blackburn, J. Lin, F. S. Dhabhar, N. E. Adler, J. D. Morrow, and Richard M. Cawthon, "Accelerated telomere shortening in response to life stress", Proc Natl Acad Sci U S A, 101(49), 17312–17315, 2004.
[60]. E. Blackburn (2009 Nobel Laureate) and Elissa Epel, "The Telomere Effect: A Revolutionary Approach to Living Younger, Healthier, Longer", January 3, 2017.
[61]. Cowan CSM, Hoban AE, Ventura-Silva AP, Dinan TG, Clarke G, "Gutsy Moves: The Amygdala as a Critical Node in Microbiota to Brain Signaling", Bioessays., 40(1), 2018.
[62]. P. Farzaehfar, "Comparative review of adult midbrain and striatum neurogenesis with classical neurogenesis", Neurosci. Res., 134, 1-9, 2018; doi: 10.1016/j.neures.2018.01.002. Epub 2018 Jan 12.
[63]. U. Rutishauser "Decision Making: A Role for the Amygdala in Translating Goals into Choices", Current Biology, 26 (22), R1177-R1179, 2016; https://doi.org/10.1016/j.cub.2016.09.050
[64]. B. De Martino, D. Kumaran, B. Seymour, and R. J. Dolan, "Frames, Biases, and Rational Decision-Making in the Human Brain", Science, 313(5787), 684–687, 2006; doi:10.1126/science.1128356.
[65]. A. Bechara, H. Damasio, A. R. Damasio, and G. P. Lee, "Different Contributions of the Human Amygdala and Ventromedial Prefrontal Cortex to Decision-Making", J. Neuroscience, 19(13), 5473–548, 1999.
[66]. J. Walbrin, P. Downing, and K Koldewyn, "Neural responses to visually observed social interactions", Neuropsychologia, 112, 31-39, 2018; https://doi.org/10.1016/j.neuropsychologia.2018.02.023

[67]. R. Saxe and N. Kanwisher, "People thinking about thinking people: The role of the temporo-parietal junction in 'theory of mind'", Neuro Image, 19 (4), 1835-1842, 2003: https://doi.org/10.1016/S1053-8119(03)00230-1
[68]. L. Q. Uddin, J. S. Nomi, B. Hebert-Seropian, J. Ghaziri, and O. Boucher, "Structure and Function of the Human Insula", J. Clin. Neurophysiol., 34(4), 300–306, 2017.
[69]. Andy R. Eugene, and Jolanta Masiak, "The Neuroprotective Aspects of Sleep", MEDtube Sci., 3(1), 35–40, 2015.
[70]. Pilon M; Zadra A; Joncas S et al., "Hypersynchronous delta waves and somnambulism: brain topography and effect of sleep deprivation", SLEEP, 29(1), 77-84, 2006.
[71]. Huber R, Ghilardi MF, Massimini M, Tononi G., "Local sleep and learning", Nature, 430,78-81, 2004.
[72]. D.M. Aslam and S. Liang, "Graphene EEG Sensors", work in progress, 2019.
[73]. M-F Kuo and M. A. Nitsche, "Effects of Transcranial Electrical Stimulation on Cognition", Clinical EEG and Neuroscience, 2012; https://doi.org/10.1177/1550059412444975
[74]. A. Fertonani and C. Miniussi, "Transcranial Electrical Stimulation: What We Know and Do Not Know About Mechanisms", The Neuroscientist, 23(2), 109–123, 2017.
[75]. Dan Buettner, "The Blue Zones: Lessons For Living Longer From The People Who've Lived The Longest"; https://s3.amazonaws.com/academia.edu.documents/38817325/BlueZonesStudyGuide.pdf?response-content-disposition=inline%3B%20filename%3DTHE_BLUE_ZONES_LESSONS_FOR_LIVING_LONGER.pdf&X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Credential=AKIAIWOWYYGZ2Y53UL3A%2F20191209%2Fus-east-1%2Fs3%2Faws4_request&X-Amz-Date=20191209T233954Z&X-Amz-Expires=3600&X-Amz-SignedHeaders=host&X-Amz-Signature=0c6cfa4bf1c758a7297aca90bbcdc47d5c256d3442a149e4fcf15dff6e1a79bf
[76]. COUNCIL FOR CREATIVE EDUCATION, FINLAND; https://www.ccefinland.org/6th-symposium-and-conference